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Masterclass

Superior labrum anterior to posterior (SLAP) rehabilitation in the overhead athlete☆

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ABSTRACT

Due to the complexity of shoulder pathomechanics in the overhead athlete, injuries located in the superior aspect of the glenoid, known as superior labral anterior to posterior (SLAP) lesions, are often a surgical and rehabilitation challenge. In an effort to determine surgical versus conservative care of SLAP lesions a thorough clinical examination and evaluation are necessary. If surgery is identified as the treatment of choice, post operative rehabilitation will vary pending surgical findings including the extent and location of the SLAP lesion, and other concomitant findings and procedures. This manuscript will provide an overview of the pathology, examination and evaluation of SLAP lesions, surgical management and post operative rehabilitation following various SLAP categories.

1. Introduction

Arthroscopic techniques have enabled a continual increased understanding of the complicated anatomical region known as the superior biceps labral complex. The advancement in surgical techniques has subsequently enabled a progression of physical rehabilitation of overhead athletes with labral injuries. A successful return to full unrestricted activities requires an integrated team approach. Andrews et al. in the mid 1980s originally described detachment of the superior labrum–biceps complex as a set of pathologies in the overhead throwing athlete (Andrews, Carson, & McLeaod, 1984; Andrews, Carson, & McCleod, 1985). A short five years later, Snyder et al. divided these biceps–labral complex lesions into four distinct subtypes and coined the now common label of superior labral anterior to posterior or “SLAP Lesions” (Snyder, Karzel, Del Pizzo, Ferkel, & Friedman, 1990) (Fig. 1). Later, others have expanded the classification system based on subtle differences that were felt to have critical implications on surgery and outcomes (Gartsman, & Hammerman, 2000; Maffet, Gartsman, & Moseley, 1995; Morgan, Burkhart, Palmeri & Gillespie, 1998). Despite the overwhelming attention the evaluation and treatment of SLAP lesions demands, the true incidence of these injuries is relatively low with an incidence of between 6 and 20% of all arthroscopic shoulder cases (Barber, Field, & Ryu, 2007; Field & Savoie, 1993; Handelberg, Willems, Shahabpour, Huskin, Kuta 1998; Hawkins, & Kennedy, 1980; Ide, Maeda, & Takagi, 2005; Kim, Ha, Kim, & Choi, 2002; Maffet et al., 1995; Mileski & Snyder, 1998; Resch, Golser, Thoeni, & Sperner, 1993; Snyder, Banas, & Belzer, 1996; Snyder, Banas, & Karzel, 1995; Snyder et al., 1990; Snyder, Rames, & Wolber, 1991; Stetson, Snyder, Karzel, Banas & Rahhal, 1998). The purpose of this article is to discuss the anatomy and classification of SLAP tears, the mechanism of injury, an evidence-based examination, surgical procedures and subsequent rehabilitation of these complicated lesions.

2. Anatomy

Because the glenohumeral joint is one of the most mobile in the human body, stability is provided as the result of a complex interaction between capsule, tendons, muscles, osseous configuration and the glenoid labrum. The biceps anchor is located at the supraglenoid tubercle. At this same area is an intermingling of fibers from the glenoid labrum. The glenoid labrum is composed of either fibro cartilaginous (Bost & Inman, 1942; Codman, 1934; DePalma, Callery, & Bennett, 1993), dense cartilaginous fibrous tissue with chondrocytes (Nishida, Hashizume, Toda, et al., 1996; Prodromos, Ferry, Schiller, & Zarins, 1990; Williams, Bannister, & Berry, 1995), or dense fibrous collagen tissue with a small transitional zone between the hyaline cartilage and fibrous labral tissue (Cooper, et al., 1992; Huber, & Putz, 1997; Moseley, & Overgaard,

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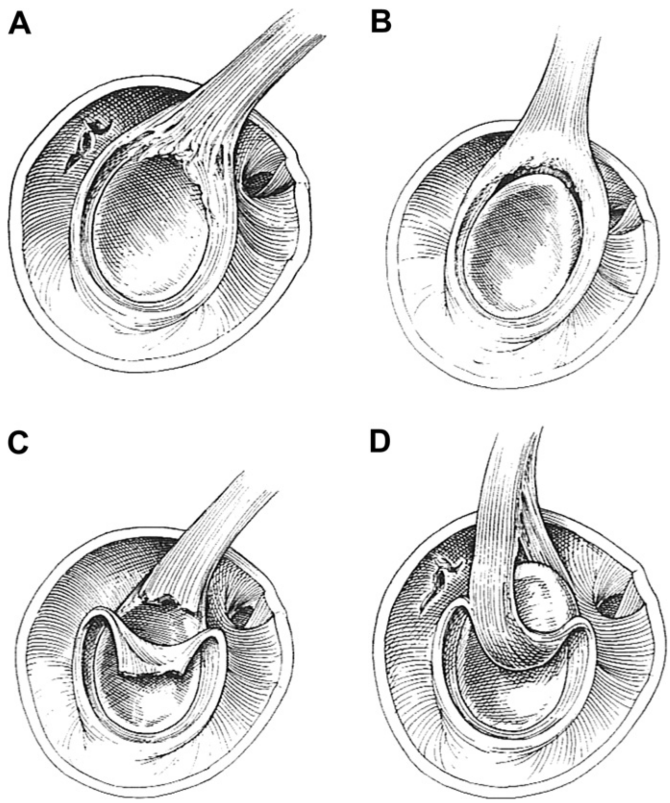

Fig. 1. Illustration of type I–IV SLAP lesions. Type I (Fig. 1A) demonstrates a frayed and or degenerative labral attachment, yet the labrum maintains a firm fixation to the glenoid rim. A type II (Fig. 1B) is a detachment of the superior biceps–labral complex attachment from the glenoid rim. A type III (Fig. 1C) is a bucket-handle tear of the labrum with an intact biceps anchor at the glenoid rim. Type IV (Fig. 1D) is a bucket-handle tear similar to type III, yet the tear extends into the biceps tendon. From: Snyder SJ, Karzel RP, Del Pizzo W, Ferkel RD, Friedman MH. SLAP Lesions of the shoulder. *Arthroscopy.* 1990; 6:274–279.

1962). This structure surrounds the glenoid fossa and assists in creating shoulder stability by deepening the glenoid. The depth of the glenoid fossa has been shown to double (2.5 mm–5.0 mm) when the labrum is present (Perry, 1978). Deepening the fossa may also allow for increased surface area contact between the glenoid and the humeral head (Cooper, et al., 1992).

As the labrum is usually firmly attached surrounding the glenoid fossa, a loosening or detachment of labral tissue could indicate an SLAP lesion. The superior labrum is looser and more mobile than its inferior counterpart which is more tightly attached to the glenoid rim (Moseley & Overgaard, 1962). At times the superior labrum has a meniscoid type free edge that extends into the joint (Fig. 2). Contrast solution used with magnetic resonance imaging (MRI) can infiltrate between the fossa and this lip of meniscal type labral tissue giving a false positive test for labral injuries. Two other common anatomical variants include the Buford complex and a sublabral foramen. A Buford complex is described as a cord-like middle glenohumeral ligament that blends with the anterior superior labrum (Williams, Synder, & Buford, 1994). When this variant occurs there is normally a loss of labral tissue from approximately the 12- to the 3-o'clock position (in the right shoulder). Neophyte arthroscopist's in the past were known to mistake this common variant for pathological labral tissue. A sublabral foramen, which is a small anterior sublabral hole, can exist inferior to the attachment of the biceps (DePalma 1993; Moseley & Overgaard, 1962). This foramen appears as a small opening or notch just above the 3-o'clock position (on a right shoulder).

These variants should not be mistaken for abnormal pathology as reattaching these tissues may cause a constrained joint.

3. History

As with most shoulder conditions, the history and physical exam are a key component in determining the correct diagnosis. Patients presenting with an SLAP lesion describe a history of painful overhead repetitive motions such as pitching, throwing, or the volleyball serve or spike. Likewise, another common history is that of a compressive injury due to a fall on an outstretched, abducted or forward flexed arm, or a traction injury from a pull (Buford, Karzel, & Snyder, 2000). A recent study of rugby players who obtained SLAP injuries found the most prevailing mechanism (83%) was that of falling directly onto an adducted shoulder or making contact with an opposing player (Funk, & Snow, 2007). A final mechanism is that of seat belt restraint, allowing the shoulder to roll around the belt strap during auto accidents (Barber, Field, & Ryu, 2007). One of the challenges of diagnosing an SLAP lesion is that patients may present with a variety of complaints. At times these complaints may mimic rotator cuff impingement, rotator cuff tears, internal impingement, and acromioclavicular joint pathology, and ganglion cysts, thus adding further confusion to an already perplexing diagnostic challenge. In a case series of 139 arthroscopy confirmed SLAP lesions, Kim et al. reported 88% to have other concomitant intra-articlar lesions (Kim, Ha, Ahn, Kim & Choi, 2003). Multiple other studies suggest that that an isolated SLAP lesion may be rare (Burkhart, Morgan, & Kibler, 2000; Coleman et al., 2007; Enad, Gaines, White, & Kurtz, 2007; Field & Savoie, 1993; Ide et al., 2005; Snyder et al., 1995).

Clustering of signs and symptoms may assist the diagnostician by giving direction toward the correct diagnosis. Although not always indicative of only SLAP lesions, these physical symptoms may include: loss of glenohumeral internal rotation range of motion, pain with overhead motions, loss of rotator cuff muscular strength and endurance, loss of scapular stabilizer muscle strength and endurance, and sensations of painful locking, catching, clicking or popping (deep within the shoulder) with shoulder movement (Gartsman & Hammerman, 2000; Kim, Ha, & Han, 1999; Kim, et al., 2001; Liu, Henry, & Nuccin, 1996; O'Brien, Pagnani, Fealy, McGlynn, & Wilson, 1998; Rodsosky, Harner, & Fu, 1994; Snyder et al., 1990) and an inability to lay on the affected shoulder (Maurer, Rosen, & Bosco, 2004). Of course generalized shoulder pain can always be a complaint which the overhead athlete translates to a loss of throwing velocity or loss of serve velocity in volleyball or tennis, and general difficulties with overhead motions (Meliski & Snyder, 1998; Barber, Field, & Ryu, 2007). Furthermore in regards to athlete's activity, overhead athletes may complain of an inability to "loosen-up" prior to activity. A key to remember in gathering the history and taking the physical examination for the athlete with a suspected SLAP lesion is that there is no single piece of history or physical finding that is truly specific for this injury and the findings are often subtle. A high index of suspicion is required when evaluating this pathology.

4. Examination

Because of the SLAP lesion being an enigmatic pathology, the number of physical examination procedures to detect its presence is high. Not all procedures are either highly sensitive or specific. Although imaging with and without contrast has a high diagnostic accuracy (Kirkley, Litchfield, Thain, & Spouge, 2003; Magee & Williams, 2006; Magee, Williams, & Mani, 2004; Sasaki, et al., 2003; Waldt, Burkart, Lange, Imhoff, Rummerny & Woertler, 2004) its cost may make it prohibitive. Additionally, a positive

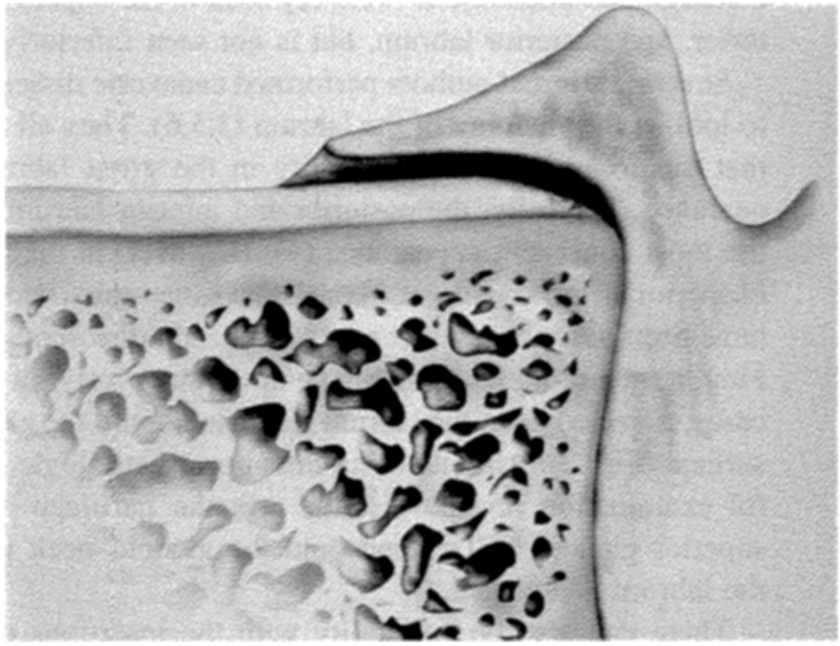

Fig. 2. Normal meniscoid type labrum. From Getelman MH, Snyder SJ. SLAP Lesions and lesions of the long head of the biceps tendon. Treatment considerations. In: Warren RF, Craig EV, Altchek DW (eds). The Unstable Shoulder. Lippincott-Raven Publishers, Philadelphia, 1999.

finding may not even result in an alteration of patient care since surgery may be required regardless. In the author's opinion a consistent thorough physical examination is the best way to determine an accurate diagnosis for labral lesions.

Multiple tests have historically been used to diagnose SLAP lesions. Table 1 describes the respective studies and findings regarding sensitivity, specificity, and positive/negative predictive values, while Table 2 includes specifics regarding each of the studies. Several of the main special tests used to diagnose an SLAP lesion are the following:

4.1. Anterior slide test

Kibler's anterior slide test (Kibler, 1995) is performed with the patient standing with arms at side, hands on hips, thumbs facing posterior to thorax. Standing behind the patient the examiner pushes the arm forward and slightly superior at the elbow along the long axis of the humerus. The patient is asked to resist the anterior superior force applied by the examiner. A positive test is indicated by a painful popping or clicking sensation.

4.2. Biceps load I

Kim (Kim et al., 1999) and colleagues described placing the patients arm in 90° of abduction and full external rotation as in the apprehension test. Once in that position the patient's forearm is supinated and they are asked to resist elbow flexion (Fig. 3). If the patient's apprehension or symptoms are decreased with that maneuver, the test is considered negative. If however, the patient has no change or a worsening of symptoms with resistance, the test is positive.

4.3. Biceps load II

Kim and colleagues (Kim et al., 2001) later described the biceps load II test by placing the patient supine with the shoulder in 120° of elevation. With full external rotation, elbow flexion of 90° and full forearm supination, the patient is asked to flex the elbow against resistance. Similar to the biceps load I test, a positive result is indicated by a worsening of symptoms.

4.4. Biceps tension test

Snyder (Snyder et al., 1990) described the biceps tension test for labral tears in which the examiner resists shoulder flexion with the patients elbow fully extended and externally rotated. This test is very similar to the Speeds test.

4.5. Compression rotation

The compression rotation test (Snyder et al., 1990) is performed with the patient supine. The affected shoulder is manually compressed through its long axis while rotated both in a clockwise and counterclockwise direction in an attempt to entrap a piece of torn labral tissue. Popping, catching, snapping pain are considered positive. Although the direction of pressure is usually into the superior portion of the labrum, it can also be directed to other regions including the anterior inferior portion for a Bankart tear or the posterior inferior for a reverse Bankart tear.

4.6. Clunk test

Andrews (Andrews et al., 1985) described the clunk test in which the patient is supine and while the examiner grasps the proximal portion of the patients affected elbow. While stabilizing the proximal hand the examiner horizontally adducts/abducts the shoulder in a motion back and forth across the frontal plane. This movement is done in an attempt to entrap a torn piece of labral tissue. As the examiner moves the shoulder back and forth, movement of the elbow into more abduction can be done to selectively test various portion of the labrum. Clicking, popping, catching and pain reproduction are considered at positive test.

Table 1
Biceps tendon and SLAP special tests sensitivity, specificity, and positive and negative predictive values, and positive and negative likelihood Ratios.

Study	Study Type	Test	Sensitivity	Specificity	PPV/NPV	PLR/NLR
Bennett et al., 1998	Prosp case series	Speed	90	13.8	23/83	1.1/0.7
Berg and Ciullo, 1998	Retro – cons rev	Slapprehension	50 Type I	NR	NR	NR
			87.5 Type 2–4	NA	NR	NR
Guanche and Jones, 2003	Cons sample	Speed	18	87	80/26	0.4/1.2
		Yergason's test	9	93	80/25	3.3/0.9
		O'Brien's test	63	73	87/40	1.1/0.9
		Jobe relocation	44	87	91/34	1.0/1.0
		Crank test	40	73	82/29	1.2/0.9
		Biccipital groove tend	44	40	69/19	1.0/1.0
Holtby and Razmjou, 2004	Prosp blinded study	Speed	32	79?	60/65	1.3/0.9
		Yergason's test	43	75	50/58	2.0/0.7
Kibler 1995	Retro – case series	Anterior slide	78.4	91.5	84/87	9.7/0.3
Kibler, Sciascia, Hester, Dome, & Jacobs, 2009	Prosp case control	Yergason's	26	70	48/48	0.86/0.0
		Speed's	29	69	48/49	0.94/1.03
		Dynamic labral shear	72	98	97/77	36/0.027
		Anterior slide	48	82	73/60	2.66/0.63
		O'Brien's test	61	84	80/67	3.8/0.46
Kim et al., 1999	Cons case series	Biceps load	90.9	96.9	83/98	29.1/0.1
Kim et al., 2001	Double blind	Biceps load II	89.7	96.6	92.1/95.5	30.0/0.1
Kim, Queale, Cosgarea, and McFarland, 2003	Prosp case control	Speed	$p = 0.004$	NA	NA	
		Active compression	$p = 0.146$	NA	NA	
Kim, Kim, Ha, Choy, Joo, and Chung, 2007	Case Series	Passive compression	81.8	85.7	87.1/80.0	5.72/0.2
Liu et al., 1996	Retro chart review	Combination	90	85	0.95/0.73	6.0/0.12
Liu et al., 1996	Case series	Crank test	91	93	94/90	13.52/0.1
McFarland et al., 2002	Case control	Active compression	47	55	10/91	1.044/0.96
		Anterior slide	8	84	5/90	0.5/1.095
Mimori et al., 1992	Pros case series	Pain provocation	100	90	97/NR	10.0/0.0
Morgan et al., 1998	Retro case series	Jobe				
		Ant	4	27	NR/NR	0.05/3.5
		Post	85	68	NR/NR	2.65/0.22
		Combo	59	54	NR/NR	1.28/0.76
		Speeds				
		Ant	100	70	NR/NR	3.33/0.0
		Post	29	11	NR/NR	0.32/6.45
		Combo	78	37	NR/NR	
		Bicepital groove tend				
		Ant	100	47	NR/NR	1.88/0.0
		Post	32	13	NR/NR	0.36/5.2
		Combo	74	35	NR/NR	1.14/0.74
		Active compression				
		Ant	88	42	NR/NR	1.51/0.28
		Post	32	13	NR/NR	0.36/5.23
		Combo	85	41	NR/NR	1.44/0.36
Myers et al., 2005	Non-rand prosp	O'Brien	54	11	70/14	0.875/2.0
Myers et al., 2005	Non-rand prosp	Resisted supination ER	83	82	92/64	4.55/0.21
Nakagawa et al., 2005		Speeds test	4	1.0	100/57	0.0/0.6
		Yergasons test	13	100	100/59	1.92/0.94
		Active compression	63	60	52/62	1.35/0.767
		Anterior slide	5	93	33/56	0.714/1.021
		Clunk	44	68	53/59	1.375/0.824
		Compression rot	25	100	100/58	0.00/0.75
		Crank	58	72	63/68	2.072/0.583
O'Brien et al., 1998	Prosp	Active compression	100	98.5	94.6/100	66.66/0.00
Parentis et al., 2006		Yergasons test	12.5	93.5	45/71	1.92/0.9636
		Active compression	54	50	35.5/75	1.25/0.75
		Anterior slide	10	81.5	19/67.6	0.55/1.104
		Crank test	12.5	82.6	23.8/68.4	1.436/1.059
		Pain Provocation	15	90.2	40/70.9	1.53/0.94
		Speeds test	47.8	67.4	34.8/72.1	1.466/0.774
Stetson and Tremplin, 2002	Non-rand prosp	Crank	46	56	41/61	1.364/0.964
		O'Brien	54	31	34/50	0.783/1.48

Cons = Consecutive; Non-rand = Non-randomized; Prosp = prospective; Retro = retrospective; PPV = Positive Predictive Value; NPV = Negative Predictive. Value; PLR = Positive Likelihood Ration; NLR = Negative Likelihood Ratio.

4.7. Crank test

In performing the Crank test as described by Liu (Liu et al., 1996), the examiner stands beside the supine or sitting patients affected extremity with the shoulder in 160° of elevation. The examiner compresses the humerus via an axial load in an attempt to scour the joint and potentially entrap a piece of torn labral tissue. The arm is then taken through internal and external rotation while still compressing the two joint surfaces. Reproduction of pain, catching, or clicking are all positive tests.

4.8. Dynamic labral shear

Kibler (Kibler, et al. 2009) has most recently described the dynamic labral shear test. This test is performed with the patient in standing and the examiner alongside the extremity to be

Table 2
Patient demographics for biceps tendon and SLAP lesion special testing studies.

Study	Test	Age (mean/range/SD)	Patient population
Bennett et al., 1998	Speed	M:16–76; F:30–80	45 patients (31 M, 14 F), 46 shoulders (26 *D*, 20 ND)
Berg and Ciullo, 1998	Slapprehension	NR	66 patients
Guanche and Jones, 2003	Speed, Yergason's O'Brien's test, Jobe relocation, Crank test, Biccipital groove tend	38(15–76)	59 patients (48 M, 11 F), 60 shoulders
Holtby and Razmjou, 2004	Speed,Yergason's	50(24–79)	50 patients (34 M, 16 F)
Kibler 1995	Anterior slide	24.6(18–32)	46 patients (30 M, 16 W) Athletes in tennis, baseball, Volleyball
Kibler et al., 2009;	Yergason's, Speed's, Dnamic labral shear, Anterior slide, O'Brien's	43.2(+/−12.6)	325 patients (232 M 93 W)
Kim et al., 1999	Biceps load	24.8(16–41)	75 patients (64 M, 11 F) Unilateral chronic dislocation, 61 *D*, 14 N)
Kim et al., 2001	Biceps load II	30.6(15–52)	127 patients (89 M, 31 F) 36 Athletics, 91 *D*, 36 N)
Kim et al., 2003	Speed, Active compression	44.2(12–86)	544 patients (309 M, 235 F)
Kim et al, 2007	Passive compression	32.6(19–54)	61 patients (57 M, 4 W) 50 Trauma, (55 *D*, 6 N)
Liu et al., 1996	Apprehension, relocation	34(17–55)	54 patients (37 M, 17 F)
Liu et al., 1996	Crank test	28(18–57)	62 patients (40 M, 22 F) 50 Recreational, (53 D, 9 N)
McFarland et al., 2002	Active compression, Anterior slide	45 (SD 17.8)	426 patients (252 M, 174 F)
Mimori et al., 1992	Pain provocation	20.9(17–29)	32 patients (30 M, 2 F) Baseball players
Morgan et al., 1998	Jobe, Speeds, Bicepital groove tend, Active compression	33(27–72)	102 patients
Myers et al., 2005	O'Brien, Resisted Supination ER	23.9(17–50)	40 (39 M, 1 F) Athletes
Nakagawa et al., 2005	Speeds, Yergasons, Active Compression, Anterior slide, Clunk, Compression rot, Crank	23(14–40)	54 (52 M; 2 F) Overhead athletes
O'Brien et al., 1998	Active compression	NR	268 patients
Parentis et al., 2006	Yergasons, Active compression, Anterior slide, Crank test, Pain Provocation, Speeds test	42(15–71)	132 patients (98 M, 34 F)
Stetson and Tremplin, 2002	Crank, O'Brien	45.9(18–75)	65 patients (45 M, 20 F) (45 *D*, 20 N)

M = Males; *F* = Females; *D* = Dominant; *N* = Non dominant; SD = Standard deviation; NR = Not reported.

tested. The patients elbow is flexed to 90° while the shoulder is abducted in the scapular plane to greater than 120°. While externally rotating the shoulder to tightness, the arm is guided into maximum horizontal abduction. The examiner imparts a shear load to the joint via lowering the arm from approximately 120–60° of abduction. It is imperative to not place the shoulder into maximal horizontal abduction until the arm is in greater than 120 of abduction. Placing the arm into horizontal abduction first created a high percentage of false-positives. A positive test is indicated by reproduction of pain and or painful click or catch between the motion of 120 and 60° of abduction.

4.9. O'Brien test (active compression test)

The O'Brien test (O'Brien, et al., 1998) is actually a combination of two tests in one, assessing both the biceps/labral attachment and the acromioclavicular joint (ACJ). The O'Brien test is performed with the examiner standing behind or beside the patient on the side of the involved shoulder. The affected shoulder is placed in a position of 90° of flexion and 15° of horizontal adduction toward the midline of the thorax. With the patients arm in full internal rotation, a downward force is applied to the distal forearm (Fig. 4), followed by the same resistance from a position of full supination and external rotation. A positive test occurs when pain is worse

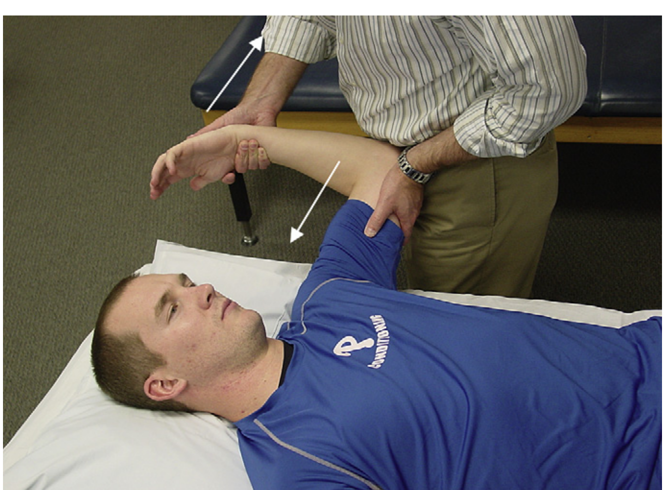

Fig. 3. The Biceps Load Test I.

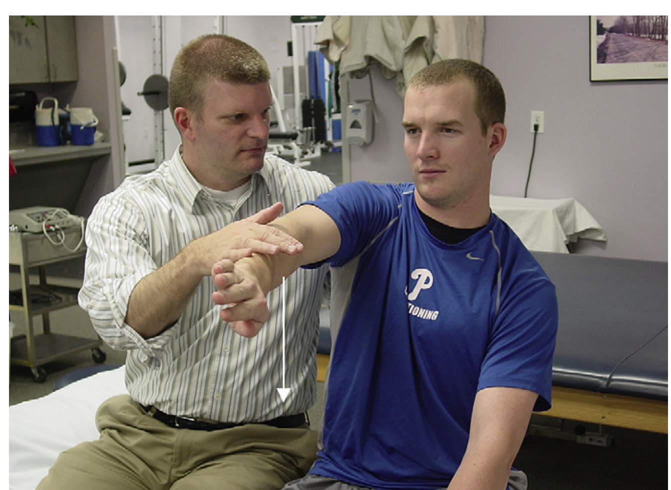

Fig. 4. Active Compression Test of O'Brien.

during internal rotation and lessens or resolves with the position of supination. The key is the location of pain. Pain on the "top" of the shoulder indicates ACJ pathology, while pain "deep" in the shoulder would indicate an SLAP tear. Since pain is the "provocation" for this test determination of an SLAP tear can be difficult as overhead throwers often have other conditions which may mimick a labral tear when placed in this position. Shoulder impingement can occur when placed in shoulder internal rotation and 90° of shoulder abduction producing shoulder pain. Additionally, posterior shoulder pain with this maneuver may be indicative of posterior capsulitis or posterior cuff muscle strain or tension while in the adducted position.

4.10. Pain provocation test

Mimori (Mimori, Muneta, & Nakagawa, 1992) described placing the supine patients shoulder in 90° of abduction and full external rotation. The patients hand is placed in either full supination, then full pronation. The patient is then asked which position provokes the most pain. If the patient has more pain with the forearm in pronation the test is considered positive.

4.11. Pronated load test

The pronated load test was recently described by Wilk, Reinold, Dugas, Arrigo, Moser, and Andrews (2005). In the pronated load test the patient is either seated or supine. The affected shoulder is placed in 90° of abduction with the forearm fully pronated. When at end range in this position the patient is asked to resist an isometric contraction of the biceps, which will simulate a peel-back lesion of the labral anchor.

4.12. Resisted supination external rotation test

The resisted supination external rotation test as described recently by Myers (Myers, Zemonavic & Andrews, 2005) positions the patient in supine with the shoulder in 90° of abduction and approximately 65° of elbow flexion. The examiner passively externally rotates the shoulder while resisting the patients attempt to maximally supinate the forearm. Pain is considered a positive test.

4.13. SLAP-rehension test

This test is a modification of the O'Brien test, in which the arm is horizontally adducted 45° versus only 15 in the original test. The increase in adduction motion is thought to place more stress on the biceps anchor. It must be remembered however, that this position is also much more likely to compress the ACJ.

4.14. Speed's test

Speeds test is performed with the examiner standing alongside the patients arm to be tested. The patient's arm is place in approximately 90° of flexion, with forearm in full supination. Resistance is given to a downward force on the distal forearm (Fig. 5). Pain produces either anterior shoulder pain or pain in the long head of the biceps and is indicative of a positive test for long head biceps pathology.

4.15. Yergason's test

Yergason's test is performed with the examiner standing beside the patients arm to be tested. With the patients arm flexed 90° at the elbow, the examiner grasps the inside of the patients arm at the wrist. The patient is asked to supinate the hand, flex the elbow and externally rotate the shoulder. Careful attention should be paid to the long head of the biceps proximally for any subluxation occurring. Pain, popping or combination of the two are indicative of a positive test of some form of pathology to the biceps long head.

Fig. 5. Speed Test.

Calvert et al., (Calvert, Chambers, Regan, Hawkins & Lieth, 2009) recently performed a systematic review of various special physical examination tests for SLAP tears and have concluded that there are serious limitations to past studies examining sensitivities and specificities for physical tests implicating these labral lesions. It is their contention that current literature used to teach medical schools and continuing education courses lacks validity, and that at present there are no good single physical examination tests that exist for effectively diagnosing an SLAP lesion.

Oh and colleagues (Oh, Kim, Kim, Gong & Lee, 2008) data suggests that combinations of 2 relatively sensitive tests (compression rotation, O'Brien's test, and anterior apprehension), and 1 relatively specific test (either Speeds test, Yergason's test, or biceps load II) increases the diagnostic efficacy of SLAP lesions. Requiring 1 of the 3 tests to be positive will result in a sensitivity of about 75%, where requiring all 3 to be positive will result in a specificity of about 90%.

A recent meta-analysis (Meserve, Cleland, & Boucher, 2009) performed examining the clinical utility of examination of SLAP lesions has concluded that the active compression, crank and Speeds test are more accurate than anterior slide at detecting a labral tear in the shoulder. Active compression appears to be the most sensitive of tests while Speeds test is most specific.

Since other concurrent pathologies can complicate examination, multiple other special tests may need to be applied to detect the presence of injuries at the acromioclavicular joint, rotator cuff, and bicipital tendon.

5. Conservative treatment

Because labral tears are common place in the athlete (Andrews et al., 1985) a course of conservative treatment is always indicated. Conservative care should focus on endurance and strength training of the rotator cuff and scapular stabilizer muscles. Posterior shoulder stretching/mobilization of capsular and cuff tightness that limits internal rotation motion should be performed and given as home exercise program. It is thought that stretching to attain full, symmetrical internal rotation may alleviate pain and symptoms associated with SLAP lesions. Relative rest from aggravating activities helps to decrease inflammation and associated symptoms so that stretching and strengthening can begin sooner. As always assessment should include a holistic approach of viewing the body and any proximal cervicothoracic and postural impairments or distal referral sources to the shoulder should be addressed. If therapy does not resolve symptoms a course of anti-inflammatory or a corticosteroid injection may give the athlete relief. When this is to no avail a diagnostic arthroscopy is usually in order.

6. Surgical treatment

Various surgical treatments for SLAP lesions can be clearly seen in Table 3. The rehabilitation described in this manuscript will discuss all SLAP lesions, but most emphasis will be placed on the type II SLAP lesion because of its acceptance as being the primary SLAP lesion repaired in overhead athletes. Although all types of SLAP tears can be treated surgically, the overwhelming amount of type II repairs significantly outnumber those of the other categories (types I, III, and IV).

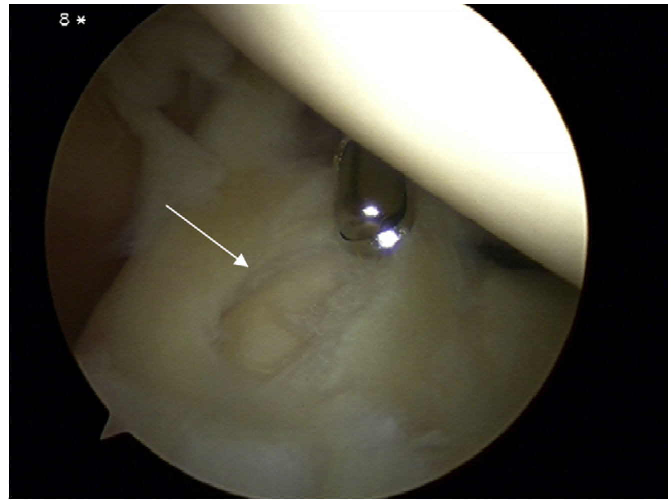

Fig. 6. Arthroscopic view of type III lesion.

7. Post surgical rehabilitation

7.1. Type I and type III lesions

There are more than likely, many overhead athletes that demonstrate fraying or a type I SLAP lesion and are still able to participate in sporting and recreational activities. Because of the loose labral tissue in the type III lesion they are probably going to be more symptomatic. At times due to instability or shoulder symptoms surgical intervention to debride the fraying labrum back to the glenoid rim for the type I lesion is required. The type III lesion (Fig. 6) will typically need to have the loose tissue removed and any fraying labrum should be debrided back to the stable rim. As long as there are no other confounding variables or concomitant procedures, rehabilitation following surgical intervention of a type I and III lesion can be fairly aggressive regarding attainment of range of motion. Since the biceps anchor has not been altered or reattached tension can be safely placed through the biceps and soft tissue healing constraints are generally lifted. Passive, active assistive and active range of motion can be initiated early, although since there may have been some debridement to the biceps anchor loading of elbow flexion may be held for about 1 week. Manual therapy treatments such as joint mobilization can be started early and should address restricted areas of the capsule including the posterior and inferior regions. Other concomitant procedures performed at the same time (capsular plication, rotator cuff tears) will require appropriately placed restrictions.

A sling should be worn for several days for comfort although almost always is discontinued by the end of the first post operative week. Active assisted range of motion (AAROM) and passive range of motion (PROM) are initiated on first post operative visit. Approximately 1 week after surgery light isotonic glenohumeral and scapular exercises are initiated. In an attempt to rest the debrided site, light biceps activity is started at the end of the second week. Isotonic exercises with bands and weights are progressed as tolerated, while more aggressive exercises such as shoulder plyometrics dedicated to acceleration and deceleration are not began until week 4–5, pending satisfactory clinical course to that point.

Table 3
Surgical treatment of SLAP lesions.

Lesion	Surgical treatment
Type I	Debridement of frayed edges
Type II	Repair biceps anchor
Type III	Debridement of bucket-handle tear
Type IV	Debridement of bucket-handle tear, repair biceps anchor, biceps tenodesis, biceps tenotomy

7.2. Type IV lesion

Surgical intervention for the type IV SLAP lesion requires debridement of the fraying tissue if it cannot be reattached. In some cases a repair similar to the type II lesion by reattaching the torn labrum back to the glenoid is done. In other cases a biceps tenodesis is required. Unless simple tissue resection is required, the post operative protocol for the type IV repair will be very similar to that of the type II SLAP lesion. If a biceps tenodesis is performed a minimum of 10 weeks is recommended without biceps activity to allow the repaired soft tissue to fully incorporate into the bone tunnels. (Fig. 7)

7.3. Type II lesion

The rehabilitation following surgical reconstruction of the SLAP II lesion will follow a more restrictive protocol devised in Table 4. Evidence for an exact optimal treatment protocol is still not available, therefore this protocol will utilize a mixture of current best evidence from existing literature and empirically based recommendations. As usual this protocol should be used solely as a set of

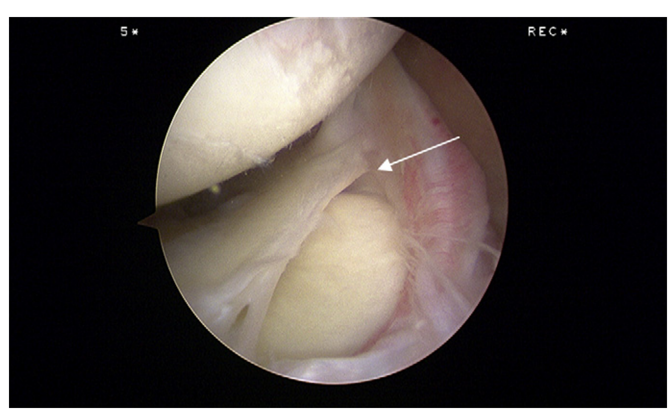

Fig. 7. Arthroscopic view of a type IV lesion.

Table 4
Rehabilitation following arthroscopic type II SLAP repair.

PHASE I: Protective Phase (Day 1 to Week 6)

Goals:
Protect the surgical repair
Decrease pain and inflammation
Prevent the negative effects of immobilization
Restore normal arthrokinematics
Prevent primary/secondary capsular hypomobility
Promote dynamic stability
Prevent reflex inhibition and secondary muscle atrophy
Develop neuromuscular control of shoulder complex
Performance of core stability

Weeks 0–2
Shoulder sling × 4 weeks
Sleep in sling × 4 weeks
Removal of sling for exercises only
Shoulder, elbow and hand ROM
- NO active isolated biceps activity (elbow flexion or forearm supination × 6 weeks)
- NO active external shoulder rotation, extension, or abduction

Hand-gripping exercises
Passive and gentle active assisted ROM exercises
- Codmans exercises
- Flexion to 90°
- Scapular plane to 90°
- External rotation to 30° × 4 weeks (approx. 10° per week after 2 nd week)
- Internal rotation to 45°
- Scapulothoracic AROM in all planes

Submaximal isometrics for shoulder musculature
Cryotherapy and modalities as needed for pain control

Weeks 3–4
Discontinue sling use at 4 weeks (Per physician approval)
Discontinue sling at night at 4 weeks
Continue shoulder, elbow and hand ROM
- Flexion to 90°
- Scapular plane to 90°
- External rotation to 30°
- Internal rotation to 60°

NO active external rotation, extension, or elevation
Initiate scapulothoracic isometrics
Initiate proprioceptive training (rhythmic stabilization drills)
Gentle submaximal shoulder isometrics
Continue use of cryotherapy as needed

Weeks 5–6
Return to light work activities
Continue to gradually improve ROM
- Flexion to 145°
- Elevation in scapular plane to 145°
- External rotation to 50°
- Internal rotation to 60°

Full ROM should be achieved at weeks 8–10
Initiate limited AROM/AAROM of shoulder to 90° flexion or abduction
Continue submaximal shoulder isometrics
Can begin AROM supination (no resistance/elbow flexed)
No biceps loading until week 10

Clinical Milestones to Progress to Phase II
- Flexion to 125°
- Abduction to 70°
- Scapular plane internal rotation to 40°
- External rotation to 40°
- *3–4/5 manual muscle test for scapular/rotator cuff muscles
- *AROM in appropriate ranges without pain

Phase II Moderate Protection Phase (Weeks 7–12)

Goals:
Progressively restore ROM (Full by week 10)
Maintain repair
Progressively restore strength and balance

Weeks 7–9
Continue to progress AROM/PROM (full by 8–10 weeks)
Begin isotonic rotator cuff internal/external strengthening with bands/weights
Progressions
- Submaximal to maximal
- Slow speeds to fast speeds
- Known patterns to random patterns
- Eyes open to eyes closed
- Open kinetic chain to closed kinetic chain

Exercises
- Scapular plane elevation
- Side lying external rotation
- Standing rotator cuff series
- Prone horizontal abduction/extension

Manual resistance to shoulder
NO biceps loading until week 10

Weeks 10–12
Initiate stretching exercises if ROM not full by 10 weeks
- Flexion to 180°
- Scapular plane elevation to 180°
- External rotation at 90° abduction to 90°
- Internal rotation at 90° abduction to 80°

Begin submaximal isometrics and AROM to biceps
Begin more aggressive exercises for rotator cuff and scapulothoracic musculature
Continue isotonic progressive resistive exercises and manually resisted exercises
Progress external rotation motion to 90/90 position
Begin submaximal exercises above 90° of elevation
Initiate “throwers ten” exercises

Clinical Milestones to Progress to Phase III
- Flexion to 160°
- Scapular plane external rotation to 65°
- Abduction to 70°
- External rotation to 40°
- External rotation at 90°–45°
- Scapular plane internal rotation full
- Internal rotation at 90° abduction to 45°
- Abduction to 150°
- Near full symmetrical posterior shoulder mobility
- *4/5 manual muscle test for scapular/rotator cuff muscles
- *Active range of motion in appropriate ranges without pain

Phase III Minimum Protection Phase (Weeks 13–20)

Goals:
Full non painful AROM/PROM
Restoration of muscle strength, power and endurance
No pain or tenderness
Gradual initiation of functional activities

Weeks 13–16
Continue stretching exercises if needed
Maintain full ROM
- External rotation @ 90° abduction up to 120° (throwers)

Initiate throwers motion
Continue phase II exercise progression and principles
Isotonic elbow flexion and forearm supination
Can increase intensity and decrease repetitions
Initiate light plyometric activities (2 handed, progressing to one)

Week 16– 20
Initiate modified throwing progressions from level surface
Continue to progress resistive exercises
Continue to progress plyometric exercises
Continue stretching exercises as needed

Clinical Milestones to Progress to Phase IV
- Within 10° of full active range of motion from opposite side in all planes of motion
- Full symmetrical posterior shoulder mobility
- 5/5 isometric shoulder manual muscle test
- 5/5 scapulothoracic and rotator cuff manual muscle test

Phase IV Advanced Strengthening Phase (Weeks 21 to 26)

Goals
Enhance muscle strength, power and endurance
Maintain shoulder AROM/PROM

(*continued on next page*)

Table 4 (*continued*)

Progress functional activities
Weeks 21–26
Initiate single arm plyometric training
Progress interval sports programs
Begin throwing from mound (weeks 24–28)
Clinical milestones to progress to phase V
Full AROM from opposite side in all planes of motion – especially
Overhead motions
Full symmetrical posterior shoulder mobility
5/5 isometric shoulder manual muscle test
5/5 scapulothoracic and rotator cuff manual muscle test
Phase V Return to Activity (Months 6–9)
Goals
Return to unrestricted sports activity
Maintain full shoulder AROM/PROM
Maintain full shoulder muscle strength, power and endurance
6 months+
Allow full velocity throwing from mound
Continue capsular stretches (especially posterior indefinitely)

guidelines as clinical judgment should supersede pending any other co-morbidities or concomitant surgical procedures (e.g., gross ligamentous laxity, capsular plication, rotator cuff tears).

7.3.1. Phase I: Protective Phase

7.3.1.1. Weeks 0–2. The protective phase is incorporated to maintain safety of the operated extremity for a short duration. This is done initially in an effort to control swelling, maintain only minimal to slight tension on the repair site and allow the normal inflammatory response to run its expected course. A shoulder sling is worn continuously for the first week (Burkhart & Morgan, 2001; Burkhart, Morgan & Kibler, 2003a, 2003b; Gartsman & Hammerman, 2000; Morgan, et al., 1998). Sling use continues, including at night for up to 4 weeks. Formal rehabilitation begins usually after the first week unless there is concern that stiffness may result at which time rehabilitation can begin as early as the 3rd to 5th post operative day. At week one gentle PROM is begun in both the scapular plane and flexion to 90°. Codman's passive pendulum exercises are allowed to help decrease the risk of capsular adhesions and to nourish the articular cartilage of the humeral head and glenoid fossa. Although Burkhart and Morgan (Burkhart & Morgan, 1998) have suggested that external shoulder rotation not be taken past 0° early, due to what they describe as the "peel-back phenomenon", we typically allow a gradual increase of external rotation of about 10° per week after week one, not to exceed 30° by week 4. Internal shoulder rotation is allowed to tolerance up to 45°. Active elbow, forearm and hand motions are allowed with the exception of elbow flexion and supination which would create active tension into the biceps anchor. Scapular muscle activation can be initiated early in side lying by moving the scapula through all available planes. Gentle submaximal isometrics can begin for the glenohumeral muscles after the 2nd week. These isometric contractions can be performed via rhythmic stabilization drills for internal/external shoulder rotation, glenohumeral flexion/extension and abduction/adduction. This form of strengthening helps to promote dynamic stabilization, joint proprioception, and neuromuscular control.

Modalities can be utilized early on in an attempt to decrease inflammation, swelling and muscle inhibition. These could include pulsed non-thermal ultrasound, electrical stimulation, and cryotherapy. There remains limited evidence that these forms of modalities actually alter healing times, so their use should be used accordingly.

Because most of the patient population having repair of the SLAP lesion are active individuals, an implementation of lower extremity, and core training program should also be added.

7.3.1.2. Weeks 3–4. The shoulder sling is slowly discontinued at or around week 4 as long as symptoms continue to decrease. During weeks 3–4, internal rotation motion can be increased up to 50°, in an attempt to stretch and mobilize the posterior capsule. One hypothesis for progression of SLAP tears, described by Burkhart, Morgan and Kibler (Burkhart, Morgan & Kibler, 2003a), is that a posterior – superior shear of the humeral head occurs during glenohumeral elevation and external rotation. This could theoretically be caused due to obligate translations as described by Harryman (Harryman, Sidles, Clark, McQuade, Gibb & Matsen 1990) and Karduna (Karduna, Williams, Williams, & Iannotti, 1996). An obligate translation is one that occurs following a tightness in capsular tissues that causes motion of a given joint segment to occur in the direction opposite the tight structures. Thus an isolated tight inferior glenohumeral ligament complex will create an obligate translation of the humeral head in a superior direction with elevation. While a tight posterior capsule will create an anterior shear with internal rotation. All other shoulder motions remain the same as week 0–2.

Although actual strengthening is not a concern at this point in the rehabilitation sequence, muscle firing and decreasing muscle inhibition is always a concern. Submaximal shoulder and glenohumeral isometrics via rhythmic stabilization drills (Fig. 8) can continue to progress, as can isometrics for the scapulothoracic musculature.

7.3.1.3. Weeks 5–6. At week 5 and 6 glenohumeral ROM is now progressed. Elevation (flexion and scapular plane) can be increased to 145° as tolerated. External rotation can progress to 50°, while internal to 60°. It is anticipated that full ROM should be achieved around 10 week or 12 weeks. Limited active assisted range of motion (AAROM) and active range of motion (AROM) can begin to 90° of elevation. This is typically progressed from a supine position where the effects of gravity are minimized, progressing to a seated or standing position where the full effects of gravity are felt. These motions should be pain free with no abnormal contortions noted.

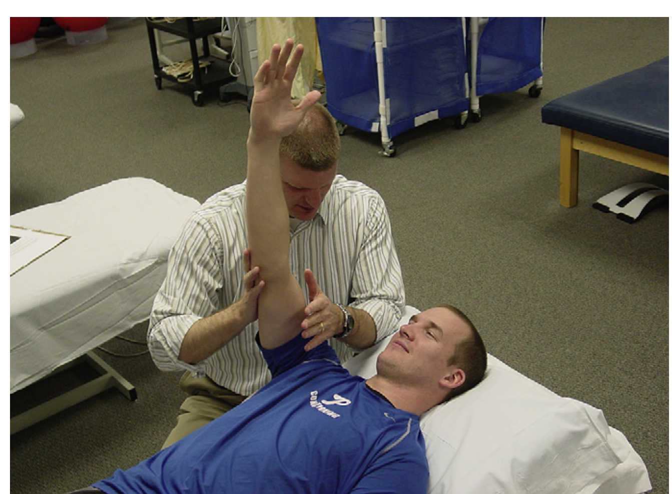

Fig. 8. Supine rhythmic stabilization drills working on early neuromuscular control, strength and endurance of shoulder musculature.

Resistance exercises or active loading of the biceps is still discouraged and will not begin until 10 weeks post operative. To maintain a decreased load on the biceps tendon even exercise such as rowing should be altered by performing with a straight arm (Fig. 9) and not allowing the arm to pass posterior to the frontal plane (Durall, Manske & Davies, 2001).

7.3.2. Phase II: Moderate Protection Phase (Weeks 7–12).

Goals change slightly in the moderate protection phase to continue progression of ROM, to maintain surgical repair and to start restoration of strength and balance of the rotator cuff and scapulothoracic muscles.

7.3.2.1. Weeks 7–9. A gradual push for full ROM of the shoulder begins at week 7 if there are remaining limitations. As long as motion is progressing nicely more aggressive treatment approaches such as stretching and joint mobilizations are not needed. Because a tight posterior capsule is thought to be a precipitator of this pathology, it should be constantly assessed. If a restriction remains the addition of posterior capsule joint mobilization techniques are beneficial. Manske et al. have shown in a randomized controlled trial that both stretching and posterior capsule joint mobilizations (Fig. 10) together are more effective at increasing posterior shoulder mobility than stretching in isolation (Manske, Meschke, Porter, Smith, & Reiman, 2010). At this point stretching can occur in higher levels of elevation and external rotation. Begin at 45° of abduction progressing to 90° of abduction for positioning the humerus during stretching of the anterior capsule. By the end of week 9, ROM for elevation should be full, external rotation should be 90°, and internal rotation should be approximately 70°.

More aggressive isotonic exercises can also be performed and includes scapular plane elevation, side lying external rotation, all rotator cuff series, and prone rowing and horizontal abduction. These exercises have been shown to demonstrate high levels of electromyographic activity in the scapular and rotator cuff muscles (Manske, 2006).

7.3.2.2. Weeks 10–12. It is at this point that submaximal isometrics can be used with the repaired biceps tendon. The initiation of the "thowers ten" can also be started (Wilk et al., 2005). Full shoulder ROM should be achieved and includes up to approximately 120° of external rotation for the thrower. Strengthening can also be progressed to the 90/90 position with manual resistance or tubing. As before these exercises in the 90/90 position should be started using submaximal resistance forces then progressing to higher levels as the patient tolerates.

Fig. 9. Safe method to begin scapular retractor strength by keeping elbow straight to not allow tension into the biceps anchor.

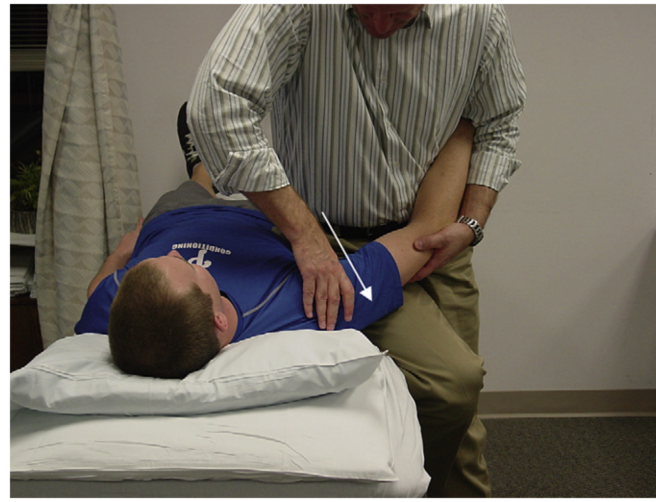

Fig. 10. Posterior capsule joint mobilizations are done to decrease risk of obligate translation in superior posterior direction which can occur if posterior inferior capsule mobility is restricted.

7.3.3. Phase III: Minimal Protection Phase (weeks 13–20)

The goals of the minimal protection phase include achieving full unrestricted, non painful AROM/PROM of the glenohumeral joint. Also the patient should have a restoration of muscle strength, power and endurance. The athlete should have no pain or tenderness in the shoulder and be able to begin a gradual restoration of functional activities.

7.3.3.1. Weeks 13–16. A continued emphasis should be placed on joint mobilization with particular attention to the posterior capsule. Self home stretches such as the cross arm stretch and the sleeper stretch should be used judiciously if limitations of motion exist. External rotation ROM should now be around 120° for throwers. Isotonic resisted exercises can commence for both elbow flexion and forearm supination. In this time frame plyometric exercises can be progressed starting with two arm throws such as chest pass, chopping motions (Fig. 11). Single-arm throws from the side for internal rotation will performed before overhead single arm or overhead double arm tosses. Weight should gradually increase starting with 2 pounds increasing to tolerance.

7.3.3.2. Week 17–21. Although there is no absolute evidence that exists describing an exact date at which throwing can commence, the 16 week point is typically the date that is used. As long as ROM is full, both rotator cuff and scapular strength are tested at full (5/5), there is no pain with overhead movements, and the athlete has passed a satisfactory clinical examination, the athlete can begin a throwing progression on level ground. Around week 14–15 very easy tossing can begin indoors from about 20 feet with a tennis ball to make sure that the athlete can transition to a starting distance of about 45 feet with an actual baseball. All throwing is to be done with a crow hop and with no pain or symptoms. When the throwing progression or interval sports program begins the athlete is usually asked to decrease their workout regimen for the shoulder to 2–3 times per week. Shoulder resistance workouts are done on the same days as the

Fig. 11. Bilateral chopping motion plyometrics with weighted ball performed late in rehabilitation to work on acceleration/deceleration activities that are required in powerful overhead motions for a full return to sporting activities.

athlete throws to ensure adequate rest interval with at least one full day between activities.

7.3.4. Phase IV: Advanced Strengthening Phase (weeks 21–26)

The main goals of the advanced strengthening phase are to maintain AROM/PROM, to enhance strength, power, and endurance of the rotator cuff and scapulothoracic muscles, and to progress the functional activities including sports and recreation.

7.3.4.1. Weeks 21–26. Single arm plyometric exercise should be able to be performed at the 21 week time frame. The throwing progression or interval sports program should be progressed as tolerated. Throwing from the mound usually occurs between 24 and 28 weeks.

7.3.5. Phase V: Return to Activity (6 months+).

The main goal in the return to activity phase is for a full return to unrestricted athletic participation.

8. Conclusions

Despite the evasiveness of diagnosing SLAP lesions therapists and physicians alike are recognizing signs and symptoms of this pathology. Due to abundance of type II lesions that are symptomatic a thorough understanding of anatomy, mechanism of injury, signs and symptoms are a pre requisite for proper conservative and surgical management. Successful treatment for SLAP lesions requires a delicate balance of regaining shoulder mobility and progression of strengthening exercises for the rotator cuff and scapulothoracic musculature. This paper has outlined pertinent anatomy, examination methods, and treatment strategies to optimize a beneficial outcomes following superior labral injury.

Ethical approval

We understand that work on human beings that is submitted to Physical Therapy in Sport should comply with the principles laid down in the declaration of Helsinki; Recommendations guiding physicians in biomedical research involving human subjects. Adopted by the 18th World Medical Assembly, Helsinki, Finland, June 1964, amended by the 29th World Medical Assembly, Tokyo, Japan, October 1975, the 35th World Medical Assembly, Venice, Italy, October 1983, and the 41st World Medical Assembly, Hong Kong, September 1989. The manuscript should contain a statement that has been approved by the appropriate ethical committees related to the institution(s) in which it was performed and that subjects gave informed consent to the work. Studies involving experiments with animals must state that their care was in accordance with institution guidelines. Patients' and volunteers' names, initials, and hospital numbers should not be used.

In a case report, the subject's written consent should be provided. It is the author's responsibility to ensure all appropriate consents have been obtained.

This is a descriptive article related to rehabilitation following SLAP lesions therefore this information does not apply.

Conflict of interest

We have no conflicts of interest to report related to this article submission.

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